Preliminary attention should be focused along the lower boundary of the figure, labeled curve 1000. On this curve, points are designated by a number of rotor blades ranging from 26 to 48 blades. These points represent the minimum speed and minimum number of vanes to be used with a particular number of blades in order that B c.p.s. decays and $2B$ c.p.s.=7000 c.p.s. with $m=8$. If, for example, 36 is initially chosen as the number of rotor blades then point 1001 gives 5960 r.p.m. and 80 vanes as the minimum speed and minimum number of stator vanes, respectively, to be used with this number of rotor blades. To investigate how the number of vanes must be adjusted if the speed is increased all that is necessary is to follow along curve 1002. This curve gives the minimum number of vanes to be used with 36 blades at any particular speed greater than 5960 r.p.m. A number of vanes larger than that specified by curve 1002 for 36 blades also satisfies the requirement that the fundamental blade passage frequency decay and that the number of lobes in the m-lobe pattern of the first harmonic is greater than 8.

Returning to the initial choice of 36 blades (point 1001), design considerations may require that the approach r.p.m. be less than the 5960 r.p.m. required if 36 blades are used. Suppose that 5000 r.p.m. is the recommended approach speed for the engine in question. Drawing the vertical line 1003 at 5000 r.p.m. it is found that there are three points labeled 1004, 1005 and 1006 which will satisfy the acoustic conditions at 5000 r.p.m. and these require 44 blades with 79 vanes (point 1004), 46 blades with 83 vanes (point 1005) or 48 blades and 87 vanes (point 1006). The final choice among these three possibilities would be point 1004 with 44 blades and 79 vanes since it is usually desirable to have as few stator vanes as possible.

Having selected the combination of blades and vanes from point 1004, it is of interest to relax the 5000 r.p.m. requirement and examine the effect of changing speed. Starting from point 1004, as speed is decreased proceed along curve 1008 toward point 1007. Point 1007 gives the minimum allowable speed to be used with 44 blades; namely, 4850 r.p.m. Recalling that 79 vanes were chosen from point 1004, it is important to note that this number of vanes also satisfies all requirements for point 1007. Parenthetically, the number of vanes to be used with 44 blades operating at a given speed must be equal to or greater than the value given by curve 1008.

Returning to point 1004, if the engine speed is to be increased above 5000 r.p.m., follow along curve 1008 to point 1009. The higher speed at point 1009, 5140 r.p.m., requires that the number of vanes be increased from 79 at point 1004 to 80 at point 1009. Now if speed is increased still further, one could proceed along a straight line connecting points 1009 and 1010 if it was only necessary that the fundamental decay. However, since it is required that $M_{2B}=|nB+kV|=|88-V|\geqslant 8$ the number of vanes must always be less than 80 or greater than 96 when B is 44 and V must be increased from 80 at point 1009 to 96 at point 1011 to allow the speed to increase. Now a speed increase means no further increase in the number of vanes required as one moves toward point 1010 on curve 1008. A still larger increase in speed from 7420 r.p.m. at point 1010 again requires a linear increase in the number of vanes.

Returning to the second example given above, a similar curve, FIG. 50, is useful. The method of calculation is analogous except it is now required that $3BN\geqslant 7000$ and that the m-lobe pattern of the first harmonic, which is to be cancelled by indexing, be a minimum of 8 lobes.

While but two examples have been given utilizing the combination of approaches including reducing the noise source, noise abatement by decay, noise cancellation by indexing, control of directivity pattern, and control of the frequency of the noise generated, numerable other combinations of these methods will be apparent to those skilled in the art on the basis of the index included therein, such that the two examples given should not be construed as limiting but purely as explanatory.

It will be obvious to those skilled in the art that for compressors used in engines having a normal operating condition it is possible, when designing the compressor, to select blade-vane combinations in the manner described herein so that the engine can be designed to experience compressor inlet discrete frequency noise abatement during the condition of normal operation, and this can be done without the requirement of indexability of parts.

It is to be understood that the invention is not limited to the specific embodiment herein illustrated and described but may be used in other ways without departure from its spirit as defined by the following claims.

Appendix A

LIST OF SYMBOLS

B=Number of rotor blades
N=Rotor shaft speed, r.p.s.
Ω=Rotor shaft speed, radians/sec.
θ=Angular coordinate, radians
t=Time coordinate
p=Pressure
n=Harmonic number ($n=1$ for fundamental)
a_n=Amplitude coefficient
ϕ_n=Phase angle
r=Radial coordinate
f=Frequency, c.p.s.
ω=Circular frequency ($\omega=2\pi f$)
x=Coordinate in direction of duct axis
y=Rectangular duct coordinate
d=Rectangular duct width
q=Index number
a_q=Pressure amplitude in cross mode q
λ=Wavelength
λ_y=Wavelength in the y-direction
c=Speed of sound in free-field
f_q=Cutoff frequency for qth cross mode
k_x=Wave number
r_0=Annular duct radius
Ω=Angular velocity of spinning pattern
s=Circumferential arc coordinate
c_s=Wave velocity in s-direction
m=Number of lobes or cycles of circumferential pressure variation
a_m=Amplitude of m-th mode
ϕ_m=Phase of mth mode
M_s=Mach number of pattern in circumferential direction
f_m=Cutoff frequency for m-lobe pattern
k_x=Wave number
Δx=Change in x position
Δdb=Sound pressure level drop
λ_s=Wavelength in circumferential direction
Ω_m=Angular velocity of m-lobe spinning pattern
σ=Hub-tip ratio ($\sigma=a/b$)
a=Inner wall radius
b=Outer wall radius
μ=Radial mode index
$E^{\sigma}_{m\mu}$=Characteristic E-function
$f_{m\mu}$=Cutoff frequency of (m,μ) mode
$k_{x\mu}$=Wave number
$k'^{\sigma}_{m\mu}$=Characteristic number
M_m=Circumferential Mach number for m-lobe pattern
M^*_m=Cutoff Mach number for (m, o) mode
V=Number of stator vanes
q=Index ($q=1,2. . .V-1$) (used differently in 4.1)
k=Index ($k=. . .-1, 0, 1, 2. . .$)
R=Radial coordinate
ψ=Angle to observer
$P_{m,\mu}$=Radiated pressure
$\xi_{m,\mu}$=Cutoff ratio